THE STATUS OF MERCURY CONCENTRATION IN FISH FROM LAKE ST. CLAIR, 1980

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Ontario
Ministry of the Environment

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Summary

This report summarizes the results of mercury analyses on over 10,000 fish taken from Lake St. Clair over the past eleven years. There is sufficient data on twelve species to demonstrate highly significant decreases in mercury concentration since the cessation of discharge of mercury by chlor-alkali operations on the St. Clair River. This decline can be well approximated by an exponential decay curve, which predicts that the levels will continue to decrease in subsequent years. The present levels are approximately one third of those observed in 1970.

Introduction

Elevated levels in fish from Lake St. Clair were first observed in 1969 (FIMREITE, 1970). Lake St. Clair is a shallow lake (average depth 3m), 1110 km^2 in area. It is situated between Lakes Huron and Erie in the Laurentian Great Lakes, and receives the majority of its inflow from the St. Clair River. Its outflow is to Lake Erie via the Detroit River.

During the 1950's and 1960's, an estimated 100,000 kg of mercury were lost to the St. Clair River from two mercury cell chlor-alkali plants operated by Dow Chemical of Canada Ltd. (OWRC 1970), downstream of Sarnia Ontario (see Figure 1). Some 18,000 kg were estimated to lie in sediments within a 20 km stretch of the river downstream of the Dow plant, while the remainder was distributed in Lake St. Clair, and western Lake Erie (THOMAS, 1974, THOMAS, JAQUET, and MURDOCH, 1975).

Lake St. Clair supported a commercial fishery that landed an annual average of over 900,000 lbs. of fish during the decade 1960-1969. Table 1 contains the yearly averages of the majory species landed during that period (ONTARIO MINISTRY OF NATURAL RESOURCES 1972a; 1972b/ 1975). The federal government banned the sale and export of fish from Lake St. Clair in March 1970 and the fishery was closed by the Ontario government shortly thereafter. The commercial fishery in Lake St. Clair remains closed for some species as of May 1981.

It had been established in September 1969 that the Dow Chemical plant was still releasing mercury to the St. Clair river (up to 31 kg/day during one survey). The plant was issued a directive from the Ministry of the Environment (then the Ontario Water Resources Commission) in March 1970 to install treatment facilities to eliminate mercury discharges to the river, and the company complied rapidly, reducing its losses to less than 0.4 kg/day by May 1970. Later, the company halted its mercury cell chlor-alkali operations altogether, and are currently using a process based on diaphragm cell.

The decline in the mercury levels in fish populations from Lake St. Clair up to 1976 was reported earlier (ONTARIO MINISTRY OF THE ENVIRONMENT 1977). The purpose of this report is to describe the situation as of the 1980 collection.

Fish Collection

For all years (1970 - 1980) except 1975, fish were captured by staff of the Ministry of Natural Resources and the Ministry of the Environment. Specimens were captured by pound and trawl net, primarily in Mitchell Bay, Tremblay Creek, Belle River, and Puce. To reduce the influence of seasonal variation, samples were always taken in October and early November.

The collection in 1975 was taken by commercial fishermen and staff from the Ministry of Natural Resources. However, this sampling was done such that limited size ranges were selectively caught, and the results from the collection in 1975 are not strictly comparable to those from the other years. In addition, weight data on fish in the 1975 collection was not recorded.

FIGURE 1: LAKE ST. CLAIR

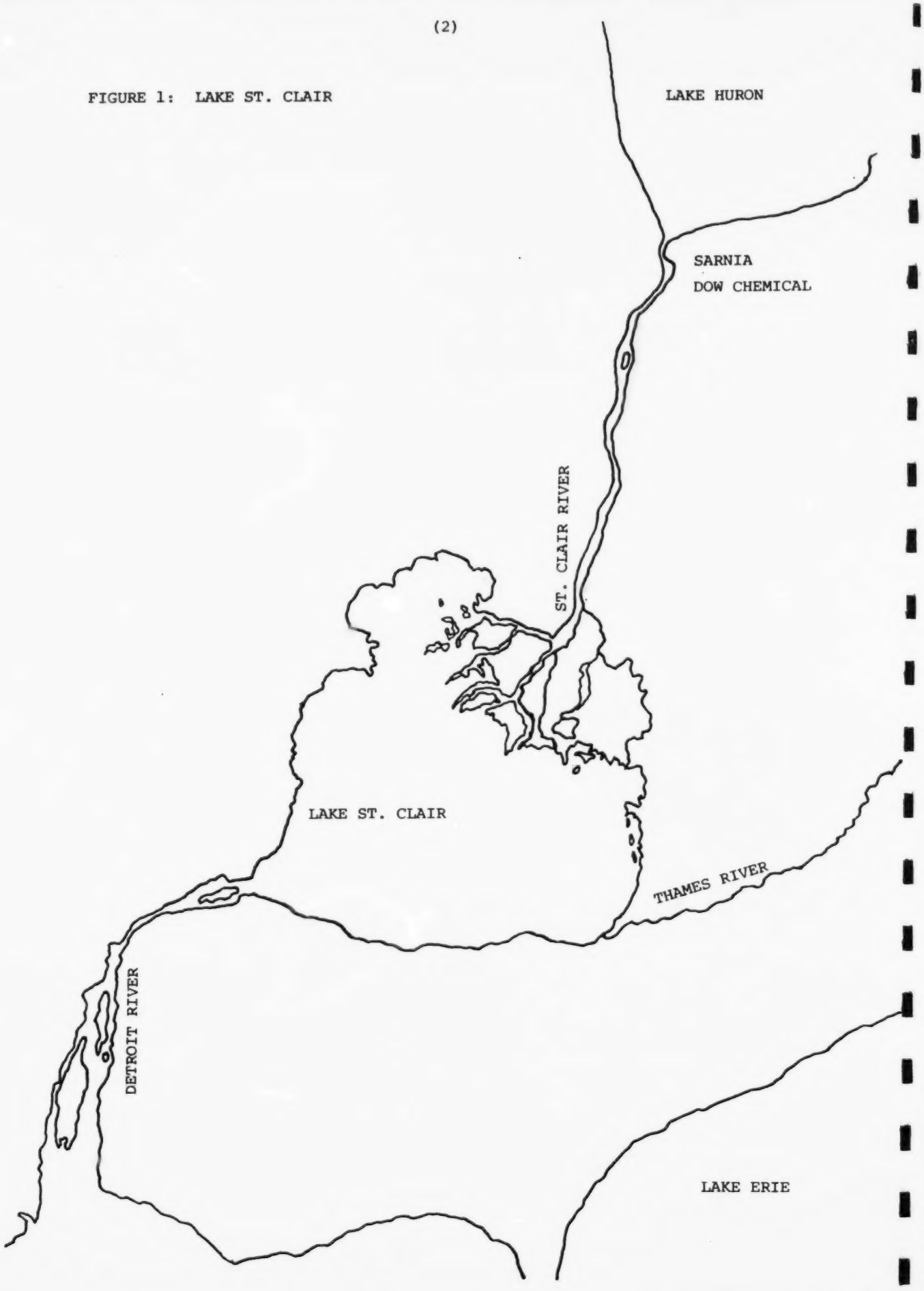

Table 1

Average Yearly Landings By

Lake St. Clair Commercial Fishermen

1960 - 1969

Species	Average Yearly landing (lb.)
"Bullheads"	9,560
Carp	235,988
Channel Catfish	75,959
Freshwater Drum	15,726
Pike	21,823
Rock Bass and Black Crappie	38,514
Sturgeon	12,611
"Suckers"	110,434
"Sunfish"	50,292
Walleye	258,128
White Bass	32,306
Yellow Perch	36,043
Other	38,514
Total	935,898

All fish captured had data on the species, length, weight, and sex (where possible) recorded by field personnel. Up to 1976, fork length data were recorded, and from 1977 onward, total lengths were taken. For comparison of fish of equal size, all lengths were converted to fork lengths as described in the section on statistical analysis. From 1970 to 1974, the frozen fish were sent to the laboratory whole, while the last four years' collections had frozen fillets submitted for analysis. The fish portion analyzed for mercury was homogenized musculature removed from the fish above the lateral line (see Figure 2), except for 1975 and 1976, where muscle tissue from the caudal peduncle was taken.

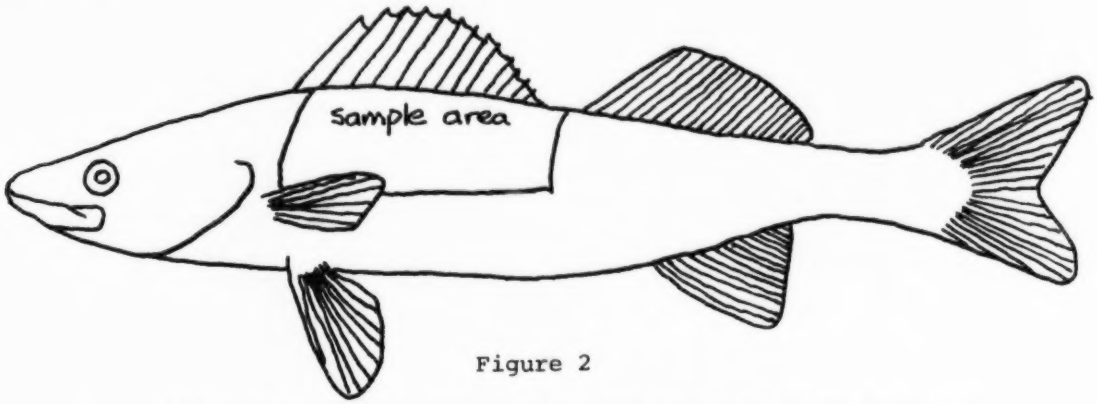

Figure 2

Altogether 10,491 representatives of 30 species have been analyzed. Table 2 contains the number of specimens analyzed from each fish species for each of the ten years of this study. A list of the common and proper names for each of the species is included in Appendix A. One species, burbot, as represented by 2 specimens and is not included in further discussions.

Table 2

Number of Specimens Collected

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	Totals
Alewife	8	-	-	69	-	-	-	-	-	-	-	77
Black Crappie	25	-	39	162	67	30	48	-	29	30	30	460
Bluegill	16	9	16	194	45	4	7	-	8	1	-	300
Bowfin	1	13	17	4	-	-	-	-	-	-	-	35
Brook Silversides	-	-	-	27	-	-	-	-	-	-	-	27
Brown Ballhead	4	8	6	109	2	-	-	-	30	30	30	219
Carp	18	29	31	105	67	33	104	51	30	30	30	527
Channel Catfish	56	13	63	100	59	82	56	51	30	30	30	570
Emerald Shiner	-	-	-	48	-	-	-	-	-	-	-	48
Freshwater Drum	9	30	47	102	62	29	-	-	30	30	-	339
Gar Pike	-	-	-	4	-	1	-	-	-	-	-	5
Gizzard Shad	-	3	-	9	-	1	-	-	-	-	-	13
Golden Shiner	-	-	-	63	-	-	-	-	-	-	-	63
Largemouth Bass	2	1	12	46	19	-	16	-	-	-	-	96
Mooneye	-	-	-	26	-	3	-	-	-	-	-	29
Muskellunge	7	8	1	4	-	4	4	-	-	6	-	34
Pike	29	43	38	101	50	4	50	17	22	27	24	405
Pumpkinseed	29	6	49	136	74	-	4	-	30	24	30	382
Quillback Sucker	4	-	7	39	26	22	-	-	19	30	-	147
Redhorse Sucker	1	-	30	51	51	20	-	-	30	30	30	243
Rock Bass	35	40	315	112	69	33	80	57	30	30	30	831
Smallmouth Bass	30	79	87	66	45	-	28	54	30	30	30	479
Spottail Shiner	-	-	-	67	-	-	-	-	-	-	-	67
Sturgeon	1	-	-	-	-	-	-	-	-	9	2	12
Trout Perch	-	-	-	10	-	-	-	-	-	-	-	10
Walleye	615	350	436	291	590	69	246	62	30	50	30	2,769
White Bass	59	1	55	99	70	48	61	61	30	30	30	544
White Crappie	-	-	-	10	2	-	-	-	-	-	-	12
White Sucker	-	-	36	51	51	33	24	-	30	30	30	285
Yellow Perch	245	70	357	375	259	22	14	54	30	10	27	1,463
Total	1,194	703	1,642	2,480	1,608	438	742	407	438	456	383	10,491

Table 3 contains a summary of the average and range of mercury, length, and weight of all fish analyzed for the 1980 collection.

Regression analyses were performed on weight versus length, and mercury concentration versus length. Because some years' collections had fork length recorded, and other years had total length recorded, all regression data used to convert total to fork length is listed in Table 4. These data were kindly supplied by Don MacLennan, Supervisor of the Ministry of Natural Resources, Lake St. Clair Fisheries Assessment Unit.

All data was logarithmically transformed to ensure data normality. The results of the regression analyses are given in Tables C-1 to C-12 in Appendix C. Covariance analysis on the weight-length and mercury-length relationships was performed within species, between years. All statistics were done on a programmable calculator according to methods outlined in SNEDECOR and COCHRANE.

Table 3

Lake St. Clair Collection - 1980

Species	N	(Hg) (Mg/Kg) Mean	(Hg) (Mg/Kg) Range	Length (Cm) Mean	Length (Cm) Range	Weight (G) Mean	Weight (G) Range
Black Crappie	30	0.58	0.15-1.38	26.0	17.4-32.8	326	82-555
Brown Bullhead	30	0.69	0.19-1.12	32.1	27.5-36.0	441	280-610
Carp	30	0.60	0.04-1.19	58.7	45.6-78.8	2992	1335-6600
Channel Catfish	30	0.74	0.18-1.87	56.6	38.7-67.1	1860	515-3535
Pike	24	1.03	0.20-2.76	65.9	31.6-85.4	1726	185-4060
Pumpkinseed	30	0.35	0.16-0.60	16.8	13.1-19.1	117	54-174
Redhorse Sucker	30	0.42	0.06-1.05	49.1	30.5-66.9	1452	255-3390
Rock Bass	30	0.57	0.20-1.25	19.9	13.3-25.1	168	42-300
Smallmouth Bass	30	0.82	0.30-1.38	37.0	28.8-46.0	810	350-1530
Sturgeon	2	1.91	0.27-3.55	121.5	103.0-140.0	11143	5140-17145
Walleye	30	0.91	0.17-2.02	49.7	33.9-69.9	1160	350-2684
White Bass	30	0.60	0.14-1.39	30.8	22.3-38.3	431	135-791
White Sucker	30	0.23	0.07-0.55	42.5	31.2-50.6	879	325-1445
Yellow Perch	27	0.33	0.10-0.97	22.5	18.7-28.8	145	70-310

Mercury Analyses

Over the ten years of this study, the analytical methodology has changed considerably. Detection of mercury in the sample has been done by cold vapour atomic absorption (HATCH and OTT 1968). However, digestion procedures have been altered considerably, with a consistent trend to higher temperatures and shorter duration. From 1970 to 1973, the procedure involved the injection of 0.3 to 0.5 g of homogenized tissue into a tared 30 ml micro-kjeldahl flask with an all glass plunger device (UTHE et al 1970). Five ml of 80% H_2SO_4, 20% HNO_3 were added, and the flasks were placed in the clamps of an oscillating water bath at 80°C for about four hours. When the solutions were clear, they were cooled, removed, and sufficient saturated $KMnO_4$ solution was added to obtain a persistent purple colour. An additional five ml of this permanganate solution were added, and the flasks were returned to the water bath for a further 1.5 hour. After cooling overnight 20 ml of distilled water and sufficient 20% hydroxylamine sulfate to reduce the excess permanganate solution were added, and the contents of the flask were washed into a 100 ml drechsel bottle, and the volume adjusted to 50 ml. Three ml of 20% stannous chloride were added, and the mercury vapour was sparged into a cold vapour tube on a Hilger-Watts Atomspek AAS tuned to 253.7 nm (BISHOP, TAYLOR, and NEARY, 1973).

The digestion technique was drastically altered in 1974 (BISHOP, TAYLOR and DIOSADY, 1975). A portion (0.2 to 0.3 g) of homogenized muscle was weighed into tared Pyrex culture tubes. Five ml of 75% H_2SO_4, 25% HNO_3 were added, and the tubes were placed in an aluminum block with holes 1 1/2" deep drilled in it sufficient to hold the bottom of the tubes. The tubes were then heated at 260°C for three hours, or until continuous white fumes. After cooling, a sufficient amount of 6% $KMnO_4$ was added to produce a persistent purple colour was added. Reduction and aeration were performed as described above, but the detection of the mercury vapour was done with a Pharmacia LDC Mercury monitor.

In 1976, the manual sparging step was replaced by an automated system. After digestion, the acids were diluted to 25 ml with distilled water, and transferred to tubes in an autosampler chain. Reduction was accomplished by a solution of 200 ml distilled water, 100 ml concentrated hydroxylamine sulfate, and 10g of sodium chloride made to 1L with distilled water. Both reduction and sparging were done in the auto-analysis train (LOESCHER and NEARY 1980).

Quality control has been accomplished through analysis of freeze dried control fish, duplicates, and spikes within each run. Also, the laboratory has participated since 1971 in an ongoing analytical round robin organized by the Freshwater Institute in Winnipeg as an external check on the accuracy of analyses.

Statistical Analyses

An examination of Table 2 reveals that many of the species are poorly represented over theperiod of this study. The following species: black crappie, carp, channel catfish, freshwater drum, pike, redhorse sucker, rock bass, small mouth bass, walleye, white bass, white sucker, and yellow perch had adequate (ten or more) sample sizes for at least six years. Summaries of the averages and ranges of mercury concentration, length and weight are attached in Appendix B. Where the sample size numbers in Table 2 and Appendix B differ, data has been discarded because of missing weight data. On this basis, all data from 1975 could not be used.

Table 3

Lake St. Clair Collection - 1980

Species	N	(Hg) (Mg/Kg) Mean	Range	Length (Cm) Mean	Range	Weight (G) Mean	Range
Black Crappie	30	0.58	0.15-1.38	26.0	17.4-32.8	326	82-555
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Pike	24	1.03	0.20-2.76	65.9	31.6-85.4	1726	185-4060
Pumpkinseed	30	0.35	0.16-0.60	16.8	13.1-19.1	117	54-174
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Smallmouth Bass	30	0.82	0.30-1.38	37.0	28.8-46.0	810	350-1530
Sturgeon	2	1.91	0.27-3.55	121.5	103.0-140.0	11143	5140-17145
Walleye	30	0.91	0.17-2.02	49.7	33.9-69.9	1160	350-2684
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White Sucker	30	0.23	0.07-0.55	42.5	31.2-50.6	879	325-1445
Yellow Perch	27	0.33	0.10-0.97	22.5	18.7-28.8	145	70-310

Table 4

Conversion of Total to Fork Lengths

Species	N	Slope	Intercept	Year
Black Crappie	63	0.9852	-0.4536	1974
Carp	51	0.9324	-1.8284	1977
Channel Catfish	51	0.9258	-1.2478	1977
Pike	99	0.9653	-1.1788	1974
Redhorse Sucker	23	0.9048	-0.0102	1978
Rock Bass	99	0.9750	-0.1626	1974
Smallmouth Bass	99	0.9494	0.0700	1974
Walleye	523	0.9430	0.0060	1974
White Bass	99	0.9068	0.3633	1974
White Sucker	31	0.9223	0.4178	1978
Yellow Perch	100	0.953	-0.0013	1974

Results

Mercury Concentrations Within Species

As can be seen from Tables C-1 to C-12, most of the slopes of the mercury-length regressions changed significantly from 1970 to 1980. Therefore, the adjusted means of the covariance analyses could not be used as estimates of the yearly mercury means of the various species. To eliminate differences in overall arithmetic mean mercury concentration due to variability in average length of the collection, a restricted size range was compared from year to year. The size range for each species was selected by taking 20 or a 10 cm interval centred on the adjusted group mean length for the larger species, and a 5 cm interval for the smaller species. The mean mercury concentration within these intervals was then calculated, and the results are shown in Table 5, and plotted in Figures 3 to 14. Data for species where the representation within the size range was less than 5 specimens were excluded.

An examination of Table 5 reveals large drops in mercury concentration within species over the period 1970 to 1980. Paired observation "t" analysis on the 1979 and 1980 means from Table 5 shows, however, that the drop in mercury concentration over the last year has not been significant ($t = 1.082$).

TABLE 5: MEAN MERCURY CONCENTRATION IN SELECTED LENGTH RANGES

SPECIES	LENGTH RANGE (cm)	1970	1971	1972	1973	1974	1976	1977	1978	1979	1980
Black Crappie	17.5-22.5	1.26(28)	-	0.94(16)	0.62(65)	0.58(26)	0.49(26)	-	0.41(10)	0.39(6)	0.26(10)
Carp	40-60	0.92(86)	1.80(26)	1.07(29)	0.89(96)	0.71(54)	0.77(78)	0.58(36)	0.78(21)	0.70(25)	0.57(24)
Channel Cat Fish	40-60	1.20(45)	1.50(13)	1.26(61)	0.95(91)	1.05(43)	0.75(48)	0.51(33)	0.55(16)	0.80(27)	0.78(24)
Freshwater Drum	25-35	-	1.15(21)	0.76(33)	0.76(71)	0.70(42)	-	-	0.54(8)	0.56(21)	-
Pike	55-75	2.87(21)	4.32(18)	4.84(16)	2.72(28)	2.08(14)	1.69(18)	-	-	1.52(9)	1.09(6)
Redhorse Sucker	30-40	-	-	2.89(13)	1.47(23)	1.37(17)	-	-	0.82(6)	0.64(9)	-
Rock Bass	17.5-22.5	2.14(39)	3.07(32)	2.01(198)	1.13(95)	1.07(36)	1.04(40)	0.78(31)	0.81(13)	0.90(22)	0.61(22)
Smallmouth Bass	30.40	2.64(27)	3.80(59)	2.46(52)	1.40(18)	1.10(21)	1.01(15)	0.84(39)	0.70(12)	0.89(17)	0.76(16)
Walleye	30-40	1.69(226)	1.23(70)	1.15(128)	0.93(48)	0.59(125)	0.49(54)	0.41(17)	0.47(6)	0.41(14)	0.33(6)
White Bass	25-30	1.99(58)	-	2.23(30)	1.08(57)	0.77(17)	0.97(32)	0.54(23)	0.60(8)	0.43(19)	0.49(11)
White Sucker	35-45	-	-	-	1.23(38)	0.94(40)	0.84(17)	0.36(13)	0.42(24)	0.42(24)	0.25(21)
Yellow Perch	15-20	1.48(93)	1.48(93)	1.45(23)	0.81(142)	0.47(138)	0.31(84)	-	0.23(9)	-	0.29(13)

FIGURE 3: BLACK CRAPPIE

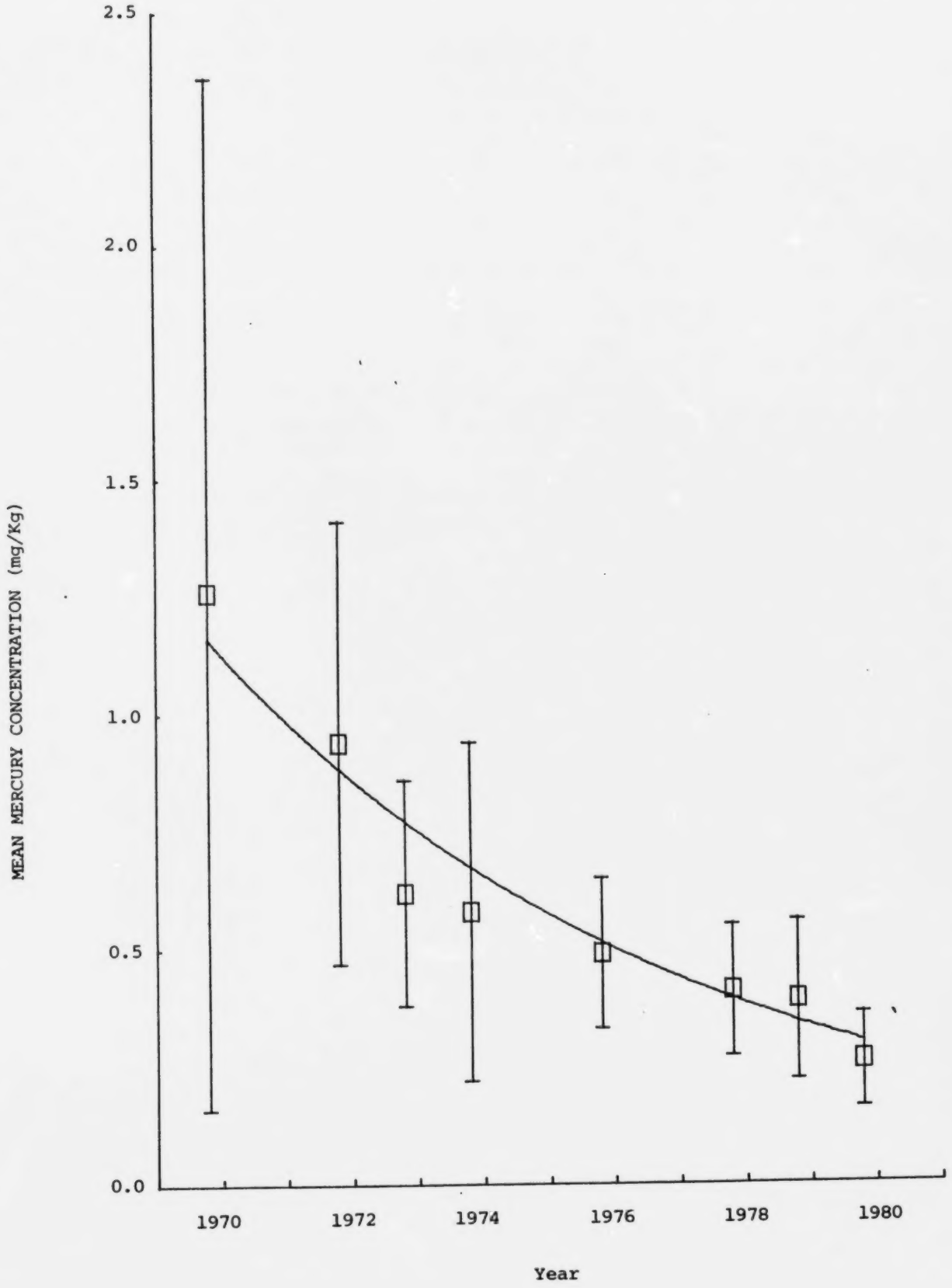


FIGURE 4: CARP

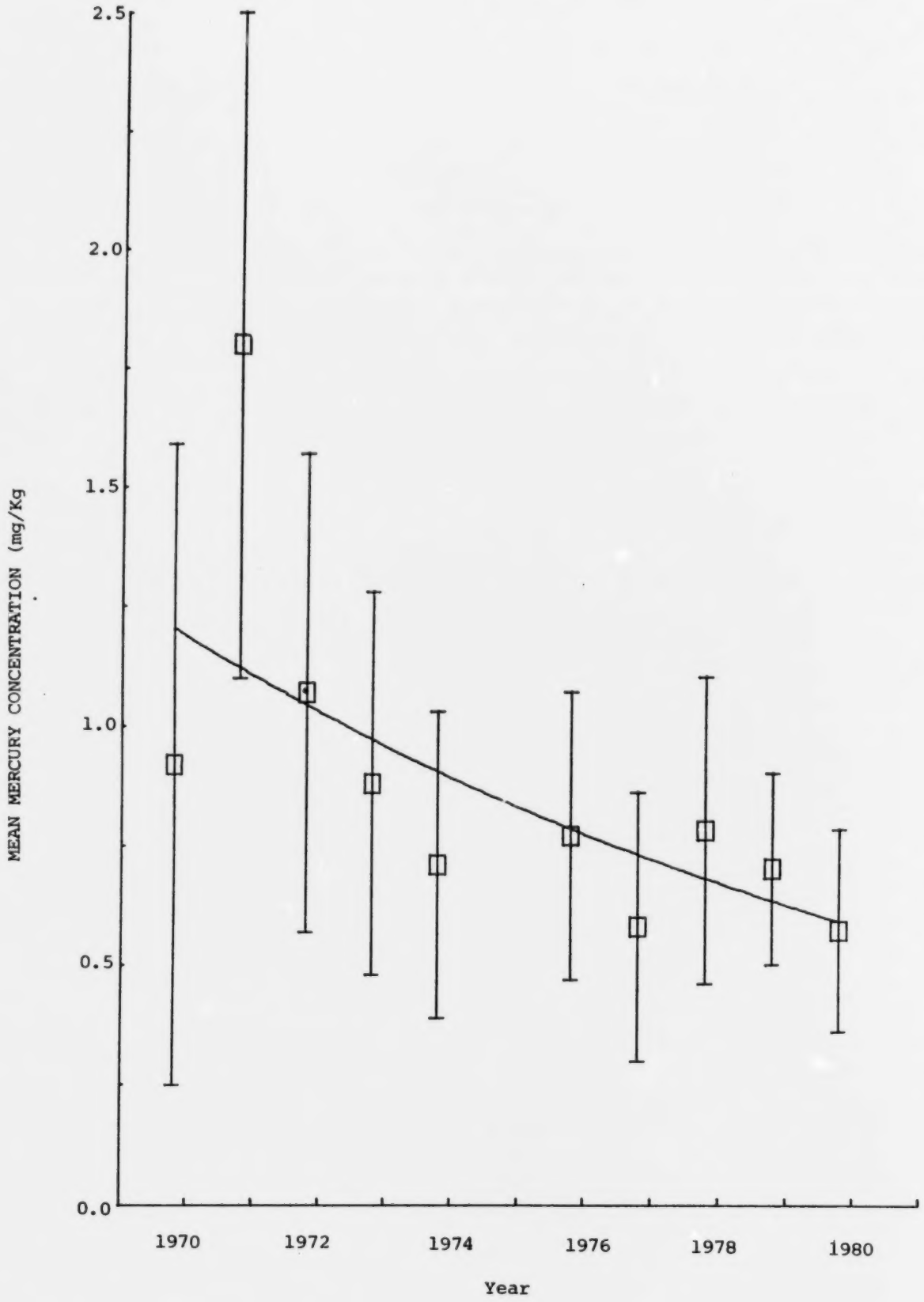


FIGURE 5: CHANNEL CATFISH

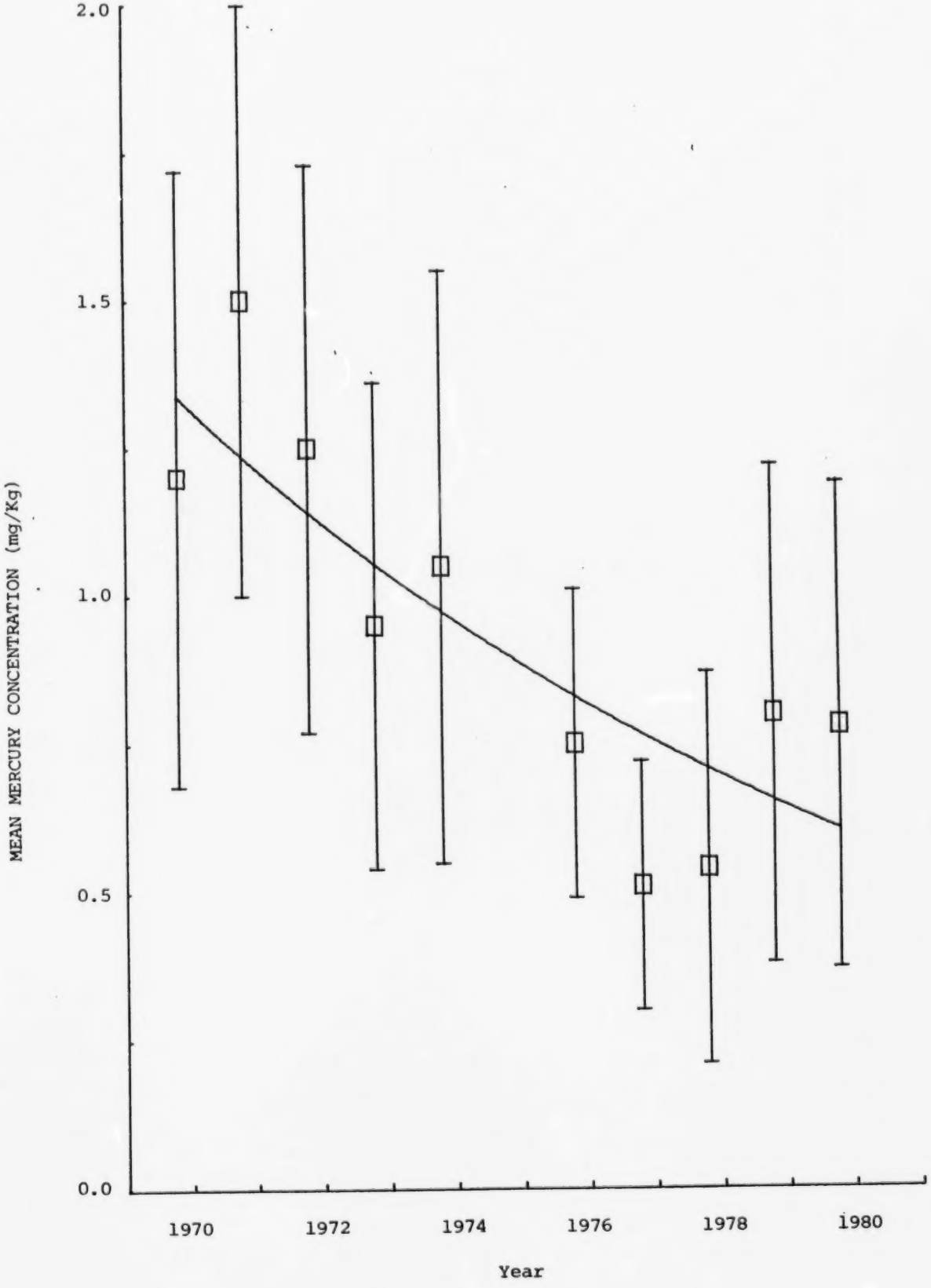


FIGURE 6: FRESHWATER DRUM

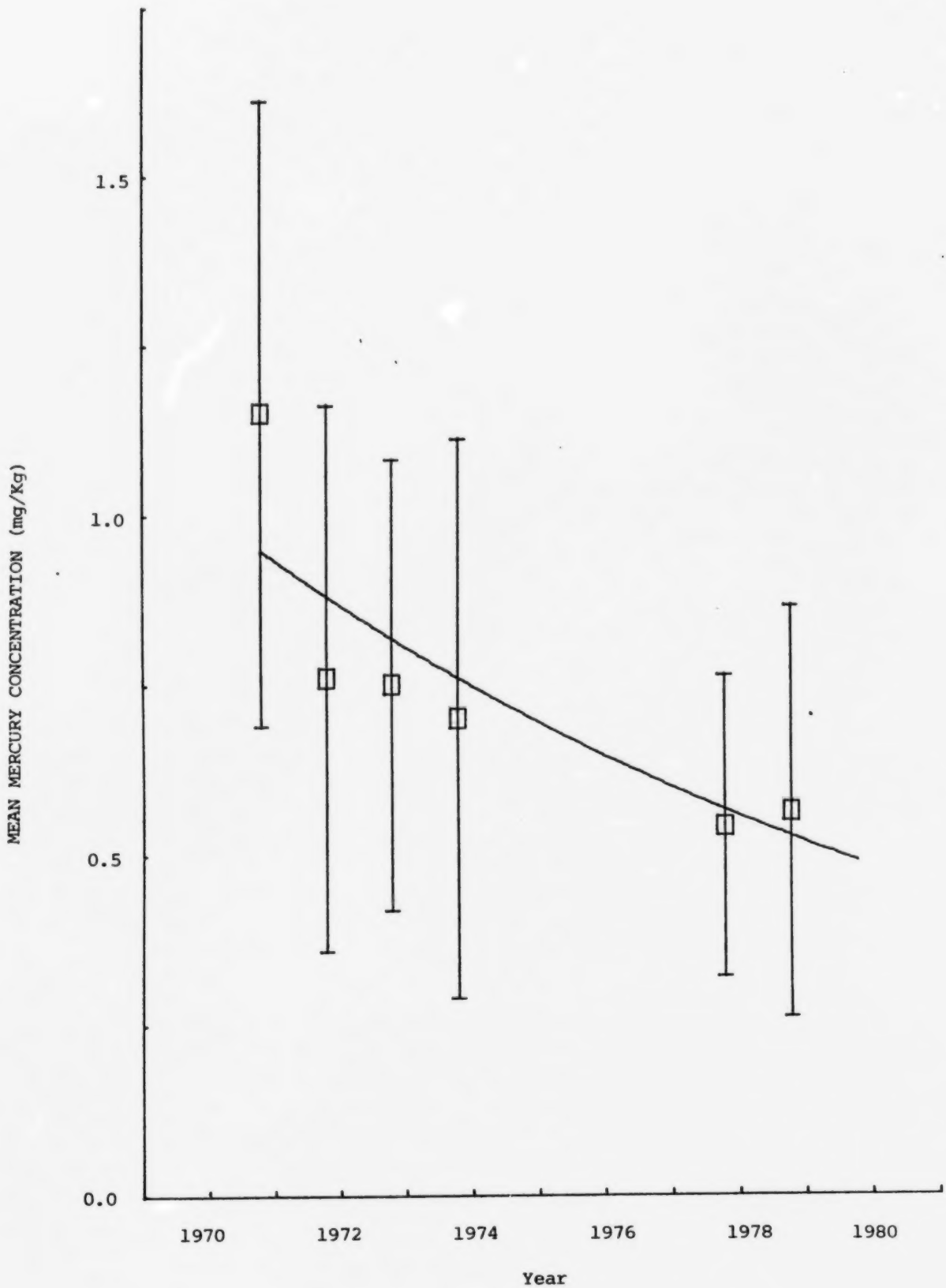


FIGURE 7: PIKE

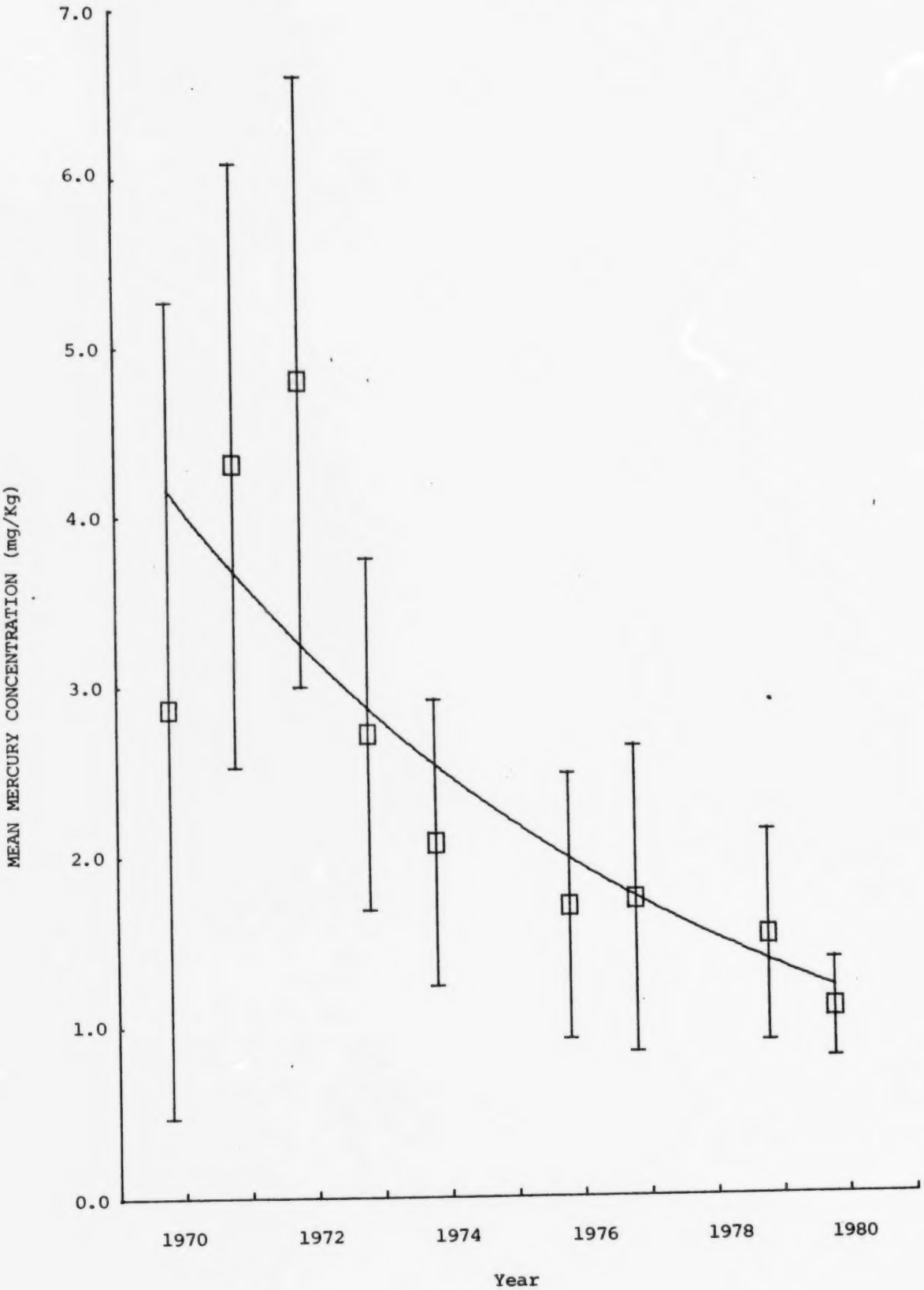


FIGURE 8: REDHORSE SUCKER

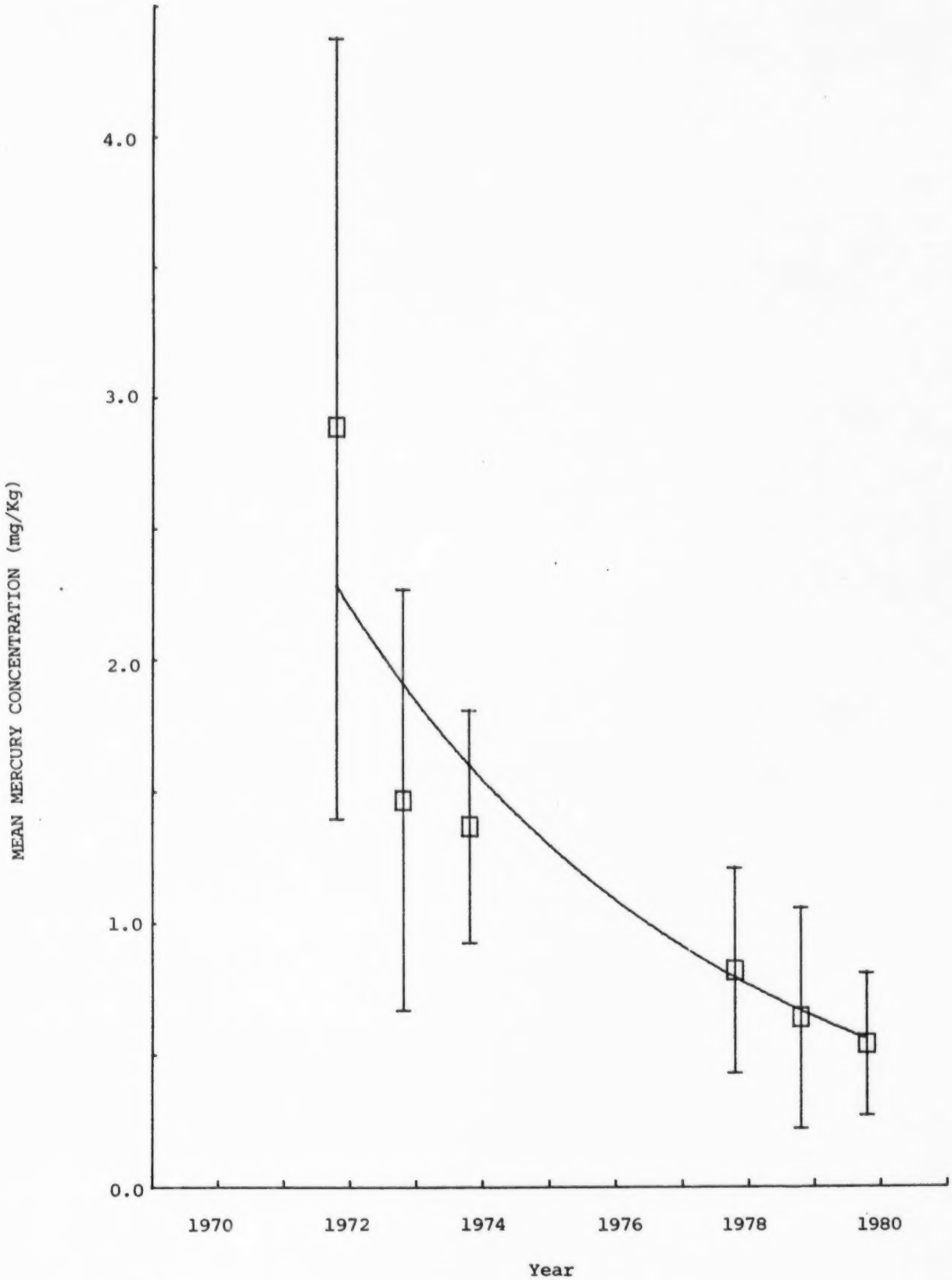


FIGURE 9: ROCK BASS

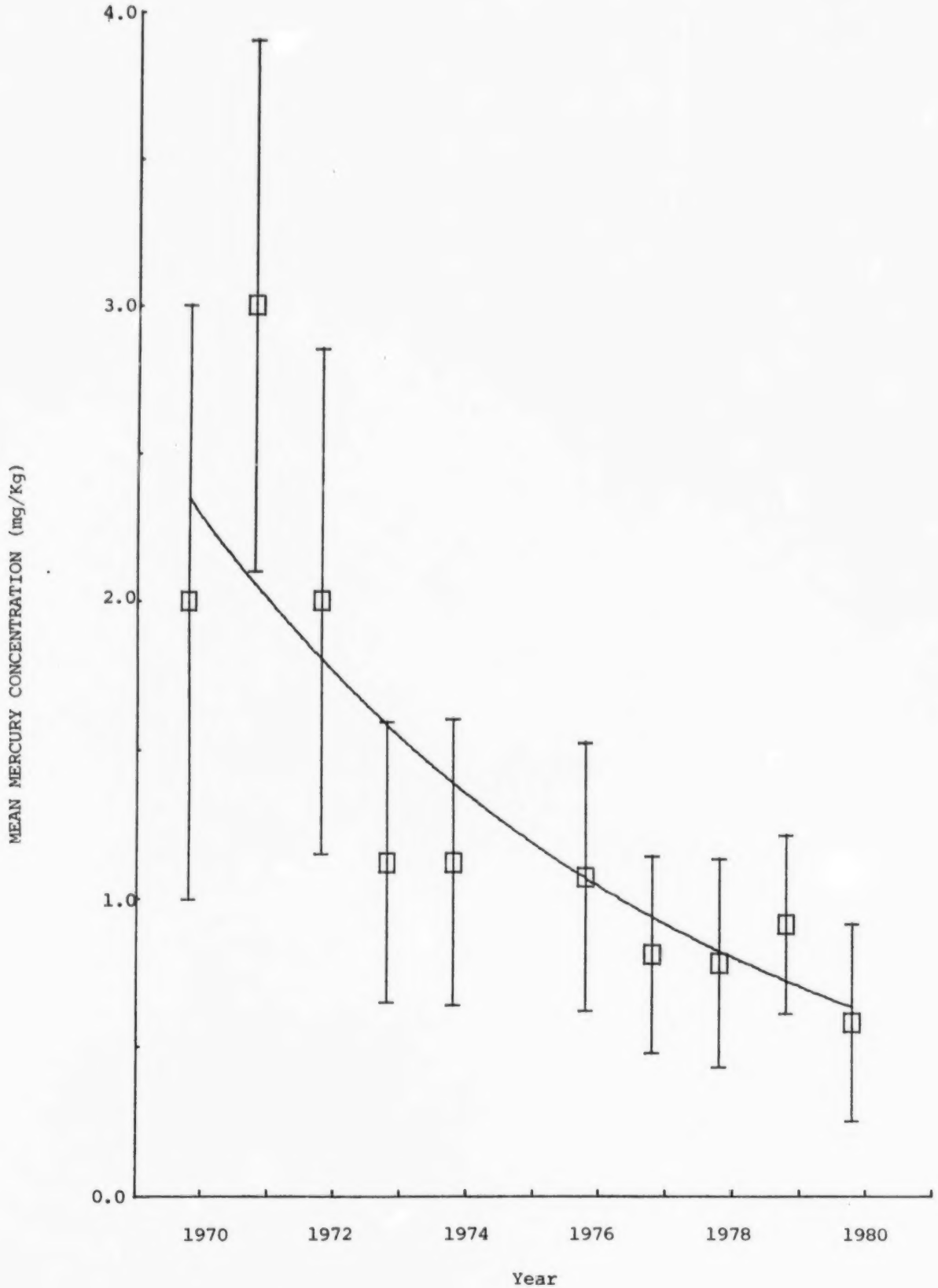


FIGURE 10: SMALLMOUTH BASS

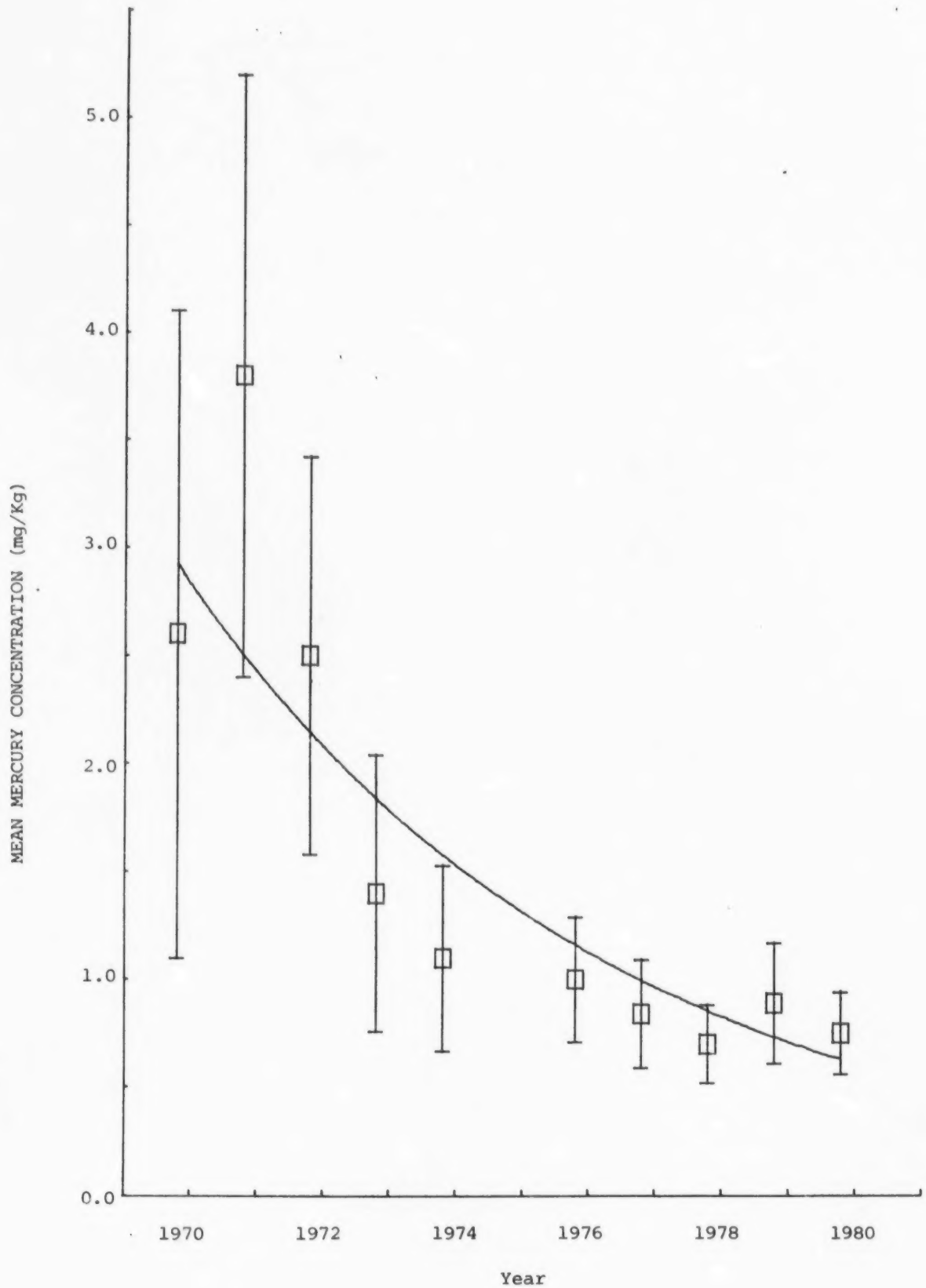


FIGURE 11: WALLEYE

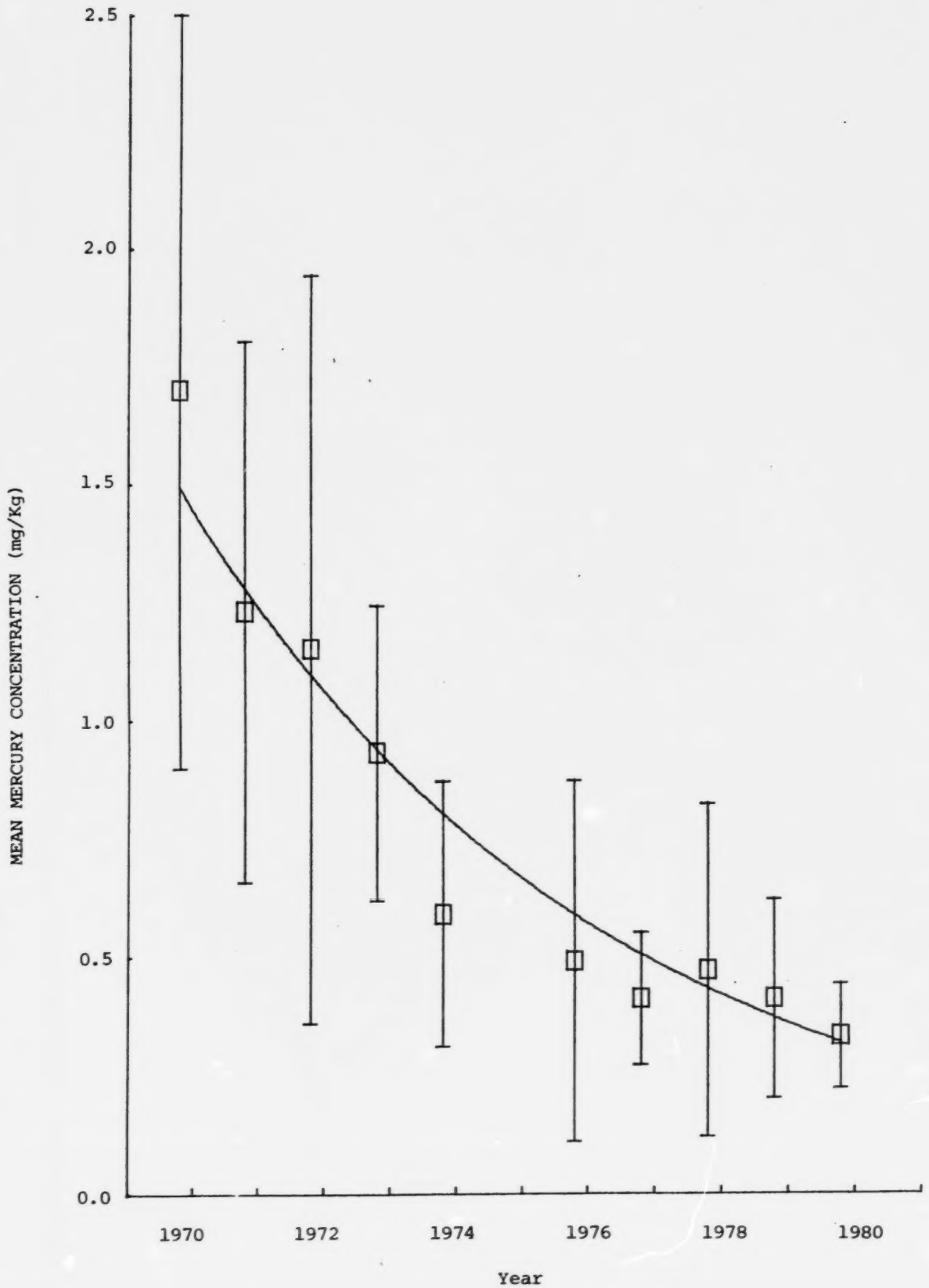


FIGURE 12: WHITE BASS

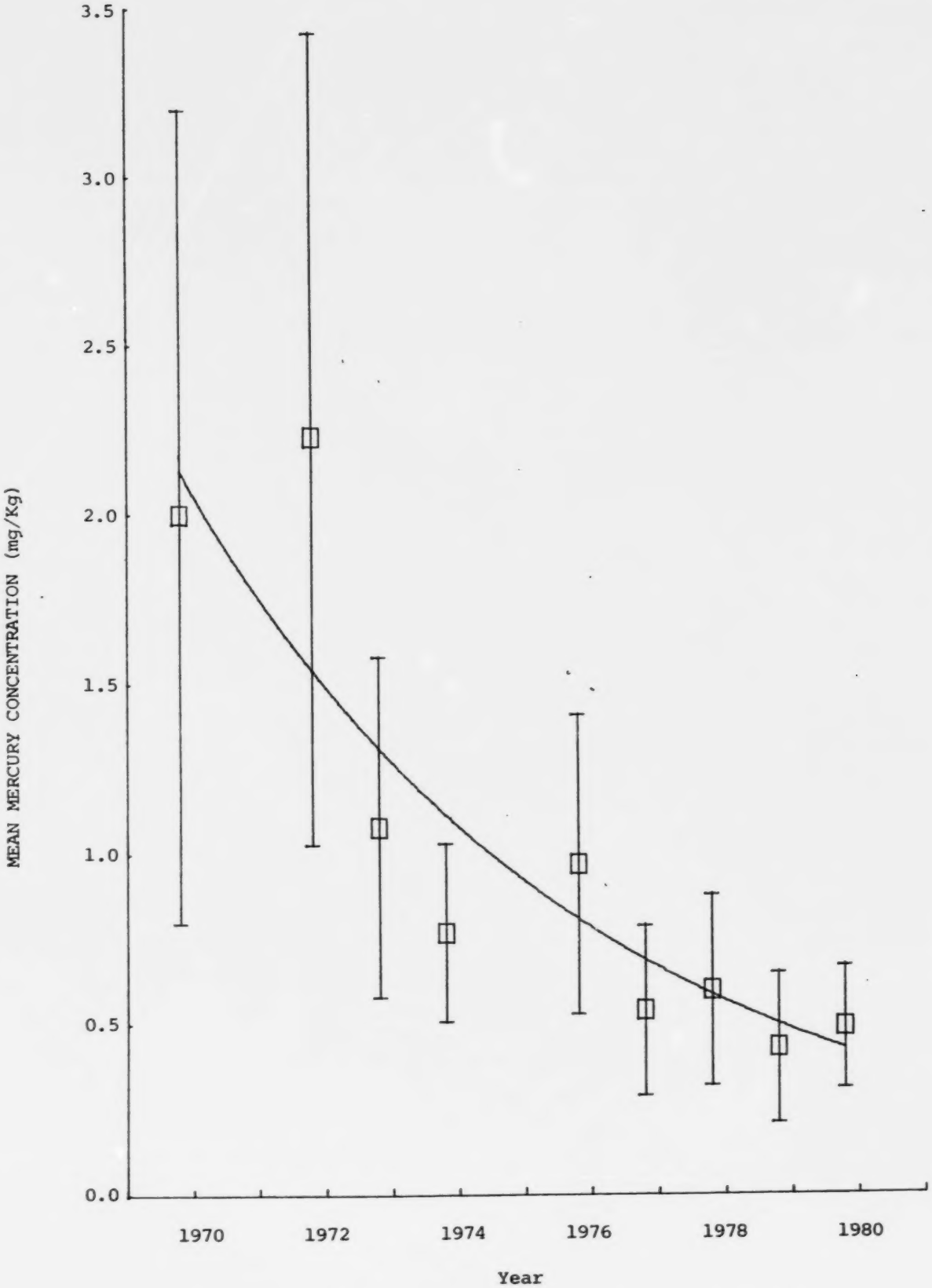


FIGURE 13: WHITE SUCKER

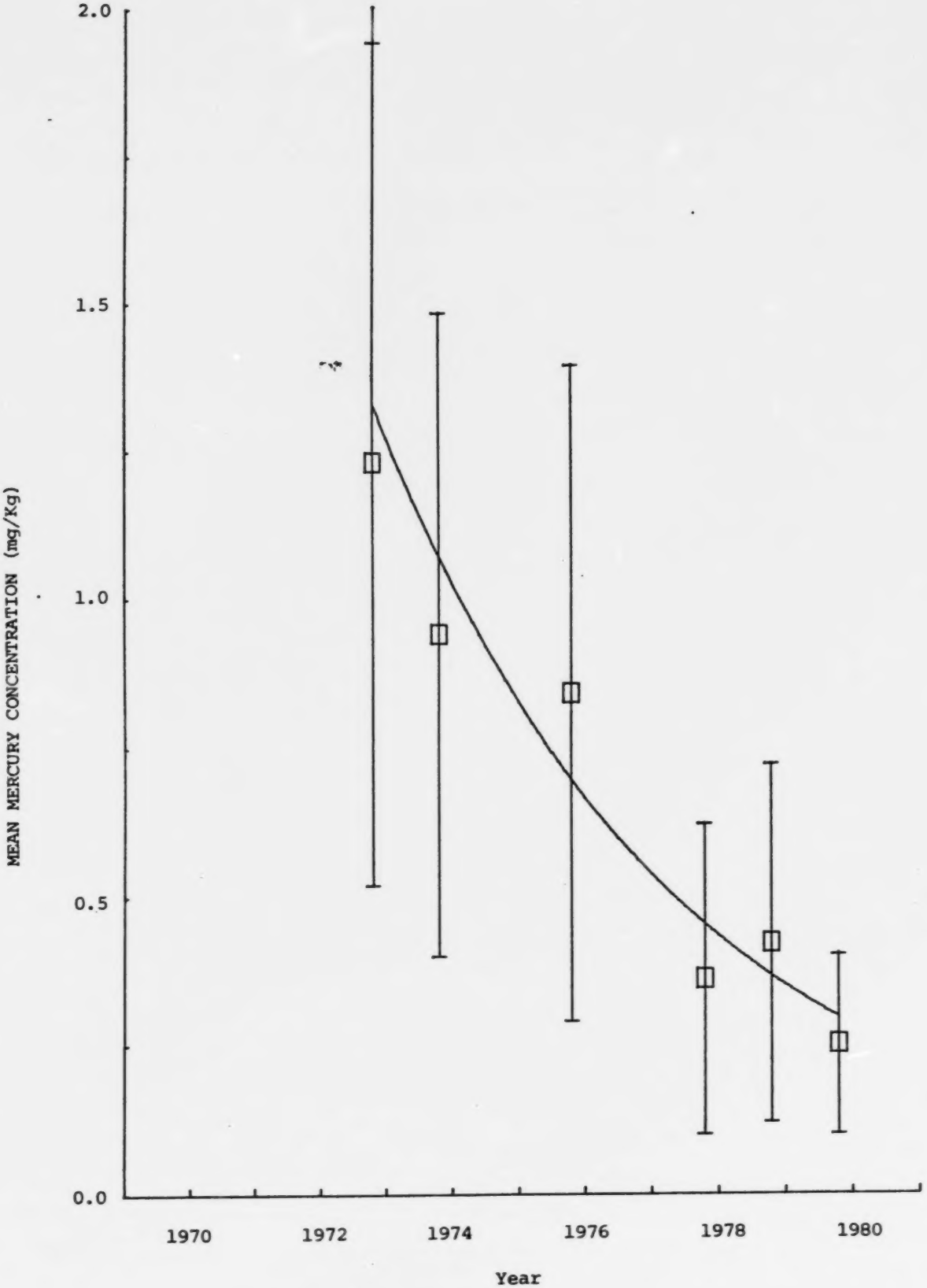
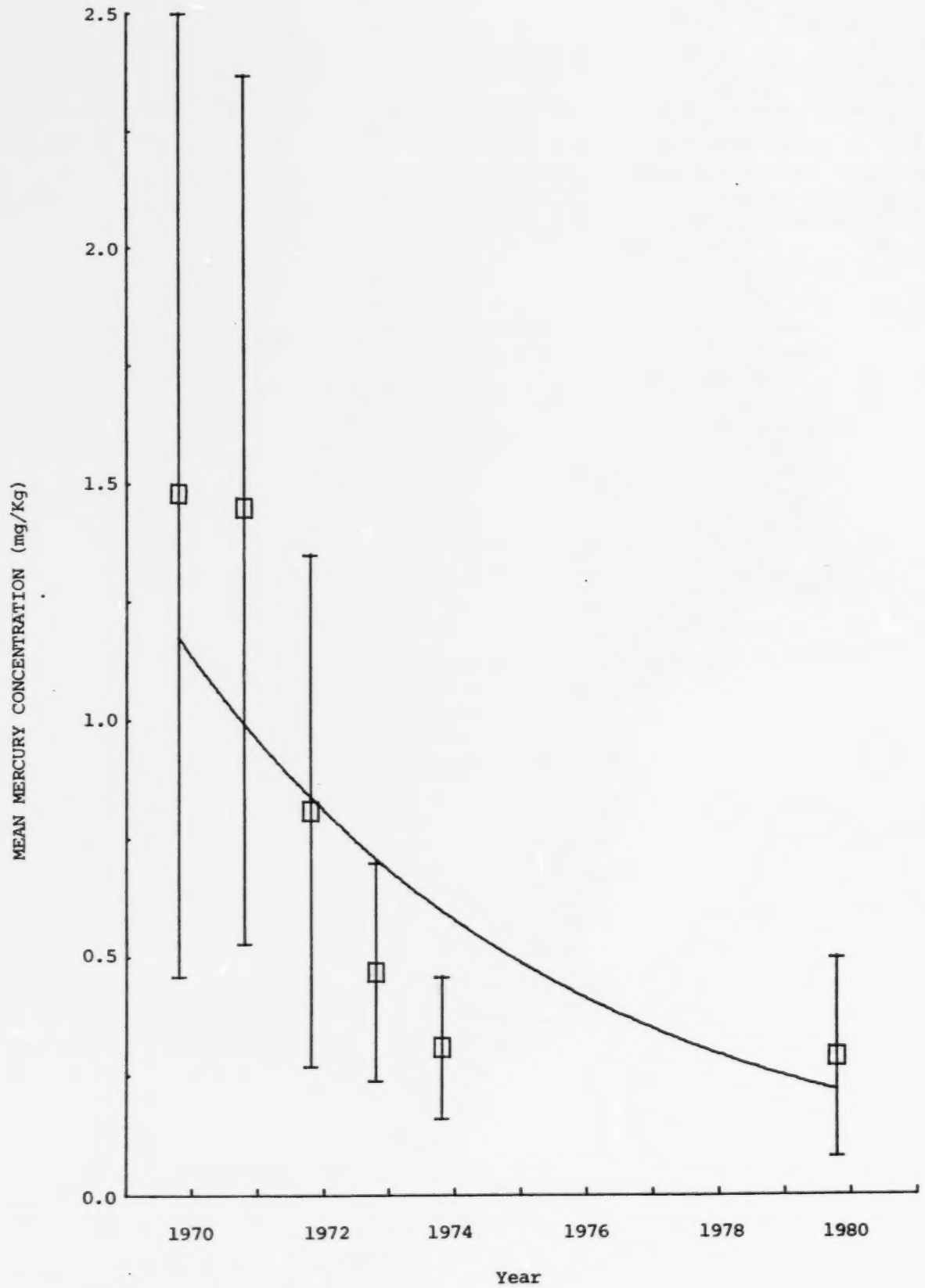


FIGURE 14: YELLOW PERCH



Discussion

The mercury concentration in all of the species for which there were good yearly collections has shown significant declines since the cessation of the discharge of mercury into Lake St. Clair. Fitting an exponential decline curve to the mean mercury concentration of specific size ranges gives a reasonable approximation of this decline, shown in Figures 3 to 14. In most cases, the correlation coefficient associated with fitting this exponential decline curve is approximately 0.9, and the half life of decline ranges from 3.2 years for white sucker to 9.7 years for carp, with an average of 5.7 years (see Table 6).

Despite the significant declines in mercury concentration in fish from Lake St. Clair, averages and ranges are still considerably higher than mercury levels encountered in the same species from the other Great Lakes. Measurable mercury residues are encountered in virtually all freshwater fish, so levels in Lake St. Clair will not decay to zero. Continuing yearly surveys have shown that the concentrations are showing a general trend to decline, and will probably continue to do so in the foreseeable future.

TABLE: 6

Species	Half-life (yr)
Black Crappie	5.1
Carp	9.7
Channel Catfish	8.7
Freshwater Drum	9.4
Pike	5.6
Redhorse Sucker	3.9
Rock Bass	5.3
Smallmouth Bass	4.5
Walleye	4.5
White Bass	4.3
White Sucker	3.2
Yellow Perch	4.1

On the basis of the data up to the 1976 collection, predictions were made on the year at which certain sizes of fish would fall below 0.5 mg/Kg mercury. The subsequent four years' decline has occurred at a slower rate than that observed during the period 1970-1976 and it appears that most of these predictions were two years early. Nonetheless, the average mercury in comparable size ranges is now 67% $\pm$ 21% of what was observed in 1976, and is 34% $\pm$ 18% of what it was in 1970, (see Table 5). It should be noted that there has been some dredging activity in Lake St. Clair since 1977,to maintain an open shipping channel. It is possible that a resuspension of mercury-containing sediments has been contributory to the observed lessening of the decline rate.

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APPENDIX A

FISH NAMES

COMMON NAME	PROPER NAME
Alewife	*Alosa pseudoharengus*
Black Crappie	*Pomoxis nigromaculatus*
Bluegill	*Lepomis macrochirus*
Bowfin	*Amia clava*
Brook Silversides	*Labidesthes sicculus*
Brown Bullhead	*Ictalurus nebulosus*
Carp	*Cyprinus carpio*
Channel Catfish	*Ictaluras punctatus*
Emerald Shiner	*Notropis atherinoides*
Freshwater Drum	*Aplodinotes grunniens*
Gar Pike	*Lepistosteus osseus*
Gizzard Shad	*Corosoma cepedianum*
Golden Shiner	*Notemigonus crysoleucas*
Largemouth Bass	*Micropterus salmoides*
Mooneye	*Hiodon tergisus*
Muskellunge	*Esox masquinongy*
Pike	*Esox lucius*
Pumpkinseed	*Lepomis gibbosus*
Quillback Sucker	*Carpiodes cyprinus*
Redhorse Sucker	*Moxostoma macrolepidotum*
Rock Bass	*Ambloplites rupestris*
Smallmouth Bass	*Micropterus dolomieui*
Spottail Shiner	*Notropis hudsonius*
Sturgeon	*Acipenser fulvescens*
Trout Perch	*Percopsis omiscomaycus*
Walleye	*Stizostideon vitreum*
White Bass	*Morone chrysops*
White Crappie	*Pomoxis annularis*
White Sucker	*Catastomus commersoni*
Yellow Perch	*Perca flavescens*

APPENDIX B

DATA SUMMARIES

Table B-1

Black Crappie

Year	N	(Hg) (mg/Kg) Mean	Range	Length (cm) Mean	Range	Weight (g) Mean	Range
1970	25	3.3	1.0 -6.1	22.8	16.1-28.4	231	61-517
1972	39	1.1	0.23-2.6	19.9	11.0-29.5	177	20-510
1973	162	0.61	0.06-2.6	18.1	5.3-33.5	142	2-530
1974	67	0.89	0.17-3.7	23.0	13.0-29.5	247	35-550
1976	48	0.69	0.22-2.0	23.3	18.0-28.4	258	100-432
1978	29	0.69	0.22-1.6	25.2	17.3-31.9	286	70-605
1979	30	0.66	0.14-1.3	25.4	20.0-30.9	297	124-502
1980	30	0.58	0.15-1.4	26.0	17.4-32.8	326	82-555

Table B-2

Carp

Year	N	(Hg) (mg/Kg) Mean	Range	Length (cm) Mean	Range	Weight (g) Mean	Range
1970	8	1.1	0.38-2.2	52.5	35.3-73.5	3114	930-8310
1971	29	1.7	0.30-3.3	48.6	30.0-58.2	2436	550-4065
1972	31	1.1	0.31-2.3	49.7	36.5-70.4	2657	1035-4865
1973	105	0.91	0.12-2.6	50.1	28.0-74.0	2750	425-7037
1974	67	0.69	0.09-1.5	48.0	37.5-83.3	2448	1015-11577
1976	104	0.79	0.16-1.5	53.8	33.5-75.4	3444	825-8855
1977	51	0.63	0.14-1.3	59.9	43.1-81.2	3341	1165-8330
1978	30	0.78	0.28-1.5	60.7	45.3-82.3	3412	315-7625
1979	30	0.67	0.34-1.2	58.0	42.9-76.0	2901	1286-6690
1980	30	0.60	0.04-1.2	58.7	45.6-78.8	2992	1335-6600

Table B-3

Channel Catfish

Year	N	(Hg) (mg/Kg) Mean	Range	Length (cm) Mean	Range	Weight (g) Mean	Range
1970	51	1.1	0.33-3.0	34.9	15.4-56.7	1273	50-2722
1971	13	1.5	0.76-2.8	52.0	48.3-56.2	2026	1350-2965
1972	63	1.3	0.53-2.8	50.2	42.8-61.7	1781	910-3165
1973	100	0.97	0.37-2.5	50.8	30.5-66.5	1864	320-4420
1974	59	0.83	0.24-3.5	48.2	26.4-65.5	1752	210-4535
1976	55	0.77	0.35-1.9	53.4	22.3-67.8	2304	200-3897
1977	51	0.43	0.15-1.0	49.2	22.2-67.1	1367	85-3785
1978	30	0.59	0.20-2.5	52.5	30.4-70.0	1612	215-3970
1979	30	0.81	0.24-2.2	54.4	45.4-69.5	1657	550-3985
1980	30	0.74	0.18-1.9	56.6	38.7-67.1	1860	515-3535

Table B-4

Freshwater Drum

Year	N	(Hg) (mg/Kg) Mean	Range	Length (cm) Mean	Range	Weight (g) Mean	Range
1970	5	1.1	0.76-1.7	22.6	21.0-26.6	152	100- 240
1971	30	1.3	0.18-3.6	32.6	21.2-41.5	459	105-1015
1972	47	0.69	0.05-1.9	29.1	18.6-49.8	322	50-1265
1973	102	0.84	0.14-2.5	31.7	18.0-56.0	431	65-1860
1974	62	0.64	0.08-4.1	28.5	19.5-47.5	297	70-1295
1978	30	0.61	0.06-1.6	32.9	14.2-52.4	531	25-1780
1979	30	0.59	0.26-1.9	33.2	23.8-57.5	553	150-2607

Table B-5

Pike

Year	N	(Hg) (mg/Kg) Mean	Range	Length (cm) Mean	Range	Weight (g) Mean	Range
1970	29	4.4	0.61-9.9	63.6	43.0-82.8	1932	500-3870
1971	43	3.9	0.29-8.5	66.0	50.4-85.5	2155	905-6020
1972	38	4.3	2.3- 9.9	71.3	56-0-85.2	2479	1080-4535
1973	101	2.5	0.30-6.4	65.6	27.3-92.5	2082	132-5370
1974	50	2.5	0.90-6.8	74.1	46.7-92.7	2866	690-5275
1976	50	1.6	0.20-3.8	68.4	45.4-91.9	2393	596-6000
1977	17	2.0	0.51-3.8	75.1	52.1-94.7	2598	655-5325
1978	22	1.4	0.34-3.2	70.7	46.7-91.1	2241	590-5255
1979	27	1.4	0.42-2.5	74.7	54.1-94.2	2611	871-5090
1980	24	1.0	0.20-2.8	65.9	31.6-85.4	1726	185-4060

Table B-6

Rock Bass

Year	N	(Hg) (mg/Kg) Mean	Range	Length (cm) Mean	Range	Weight (g) Mean	Range
1970	35	3.4	0.97-11.0	19.8	12.6-29.7	185	41-345
1971	40	3.0	1.4 - 6.3	20.4	14.5-25.2	211	80-375
1972	315	1.9	0.22-5.7	17.2	5.0-28.9	87	1-300
1973	112	1.1	0.23-3.8	19.5	9.1-27.0	179	17-420
1974	69	1.1	0.22-2.4	20.2	13.4-28.0	191	50-365
1976	77	1.1	0.17-2.2	20.9	14.4-25.9	212	63-365
1977	57	0.84	0.20-1.7	21.3	14.4-26.8	204	65-400
1978	30	0.73	0.11-1.5	20.3	12.1-26.5	180	35-368
1979	30	0.91	0.29-1.4	21.9	13.2-27.3	220	44-390
1980	30	0.57	0.20-1.3	19.9	13.3-25-1	168	42-300

Table B-7

Smallmouth Bass

Year	N	(Hg) (mg/Kg) Mean	Range	Length (cm) Mean	Range	Weight (g) Mean	Range
1970	23	3.0	1.0-6.9	32.4	22.0-44.0	640	220-1430
1971	79	3.3	1.1-7.2	32.8	19.9-39.9	670	130-1175
1972	87	2.4	0.30-6.7	33.4	19.5-48.2	696	115-1760
1973	66	1.4	0.43-3.5	33.2	22.5-49.5	738	210-2150
1974	45	1.5	0.55-4.8	35.0	17.5-47.8	800	85-1945
1976	28	1.2	0.24-3.7	35.1	17.6-46.3	802	153-1600
1977	54	0.79	0.30-1.6	34.1	20.1-42.5	658	115-1230
1978	30	0.73	0.21-3.8	34.4	19.7-52.8	703	117-1875
1979	30	0.86	0.22-1.9	37.2	24.5-54.5	878	235-2400
1980	30	0.82	0.30-1.4	37.0	28.8-46.0	810	350-1530

Table B-8

Walleye

Year	N	(Hg) (mg/Kg) Mean	Range	Length (cm) Mean	Range	Weight (g) Mean	Range
1970	611	2.1	0.23-14.0	34.8	11.7-70.7	640	13-3010
1971	350	1.8	0.13-13.1	35.1	15.0-63.0	599	38-2365
1972	436	1.3	-.13- 7.1	33.5	12.2-68.5	581	15-3100
1973	291	1.1	-.13- 5.0	40.2	13.0-67.5	853	22-3095
1974	590	1.0	0.10- 3.2	41.8	14.3-67.7	959	27-3315
1976	246	0.93	0.11- 3.0	47.3	27.4-70.6	1278	205-4087
1977	62	0.97	0.16- 2.7	49.6	33.9-69.3	1216	325-2830
1978	30	0.70	0.14- 1.8	49.8	29.1-68.4	1262	165-2713
1979	30	0.88	0.11- 2.0	47.3	32.1-67.9	1055	295-2660
1980	30	0.91	0.17-2.0	49.7	33.9-69.9	1160	350-2684

Table B-9

White Bass

Year	N	(Hg) mg/Kg Mean	(Hg) mg/Kg Range	Length (cm) Mean	Length (cm) Range	Weight (g) Mean	Weight (g) Range
1970	57	2.2	0.47-5.7	25.5	11.5-33.4	312	21-700
1971	1	1.4	- - -	28.0	- - -	430	- - -
1972	55	2.0	0.34-5.5	28.1	20.0-37.3	430	120-970
1973	99	1.2	0.19-3.0	27.3	10.5-33.5	406	16-710
1974	70	0.79	0.19-2.2	26.4	19.9-34.7	354	115-855
1976	65	0.93	0.10-2.0	31.3	18.5-46.3	802	153-1000
1977	61	0.79	0.08-1.9	32.7	25.3-39.6	506	210- 815
1978	30	0.76	0.19-2.8	30.7	23.5-37.9	417	165- 770
1979	30	0.64	0.09-1.5	31.6	25.9-39.5	459	247- 857
1980	30	0.60	0.14-1.4	30.8	22.3-38.3	431	135- 791

Table 10

White Sucker

Year	N	(Hg) mg/Kg Mean	(Hg) mg/Kg Range	Length (cm) Mean	Length (cm) Range	Weight (g) Mean	Weight (g) Range
1972	36	1.4	0.25-4.0	41.8	34.5-49.8	1033	585-1465
1973	51	1.2	0.22-3.1	40.8	7.8-49.0	979	6-1655
1974	51	0.93	0.11-2.1	40.8	27.6-50.2	900	46-1645
1976	23	0.83	0.06-1.9	42.5	34.6-49.9	1064	580-1690
1978	30	0.42	0.08-1.6	40.5	23.6-52.5	786	130-1545
1979	30	0.44	0.03-2.1	43.4	36.9-50.2	907	549-1300
1980	30	0.23	0.07-0.55	42.5	31.2-50.6	879	325-1445

Table B-11

Yellow Perch

Year	N	(Hg) (mg/Kg) Mean	Range	Length (cm) Mean	Range	Weight (g) Mean	Range
1970	245	1.9	0.02-8.2	21.2	11.7-31.5	136	8-525
1971	70	1.5	0.13-3.5	16.0	6.8-31.2	99	4-390
1972	357	0.90	0.05-3.3	17.2	5.0-28.9	87	1-300
1973	375	0.45	0.08-2.1	16.2	6.6-29.0	69	4-395
1974	259	0.36	0.08-1.7	17.0	5.5-28.2	87	2-315
1976	14	0.98	0.11-2.9	22.4	17.7-26.5	159	70-250
1977	54	0.44	0.06-1.2	24.0	17.0-32.1	178	55-410
1978	30	0.56	0.22-1.1	25.8	17.9-33.3	221	56-570
1979	10	0.49	0.22-1.27	23.6	17.4-29.3	166	54-340
1980	27	0.33	0.10-0.99	22.5	18.7-28.8	145	70-310

APPENDIX C

REGRESSION COEFFICIENTS

AND

COVARIANCE ANALYSIS

TABLE C-1

BLACK CRAPPIE: Regression Coefficients

Year	N	log (Hg) on log length			log weight on log length			adjusted group means		
		A_o	A_1	r^2	A_o	A_1	r^2	length (cm)	weight (g)	(Hg) mg/kg
1970	25	-5.624	1.803*	0.057	-4.750	3.247**	0.909	20.6	162	0.88
1972	39	-5.477	1.809**	0.481	-4.284	3.096**	0.904	20.6	161	0.97
1973	162	-3.791	1.099**	0.487	-4.241	3.072**	0.960	20.6	157	0.67
1974	67	-10.361	3.213**	0.594	-4.671	3.221**	0.987	20.6	162	0.63
1976	48	-10.529	3.184**	0.509	-4.461	3.163**	0.917	20.6	167	0.50
1978	29	-7.986	2.350**	0.561	-4.908	3.274**	0.985	20.6	152	0.48
1979	30	-9.818	2.907**	0.470	-4.589	3.195**	0.870	20.6	163	0.46
1980	30	-10.852	3.148**	0.776	-4.312	3.100**	0.990	20.6	159	0.36

Covariance: Slopes: F = 7.686** (7,462)
Means: F =14.097** (7,475)

Slopes: F = 0.413 (7,462)
Means: F = 0.964 (7,475)

TABLE C-2

CARP: Regression Coefficients

Year	N	log (Hg) on log length			log weight on log length			adjusted group means		
		A_o	A_1	r^2	A_o	A_1	r^2	length(cm)	weight(g)	(Hg) (mg/Kg)
1970	8	-2.930	0.673	0.029	-3.716	2.948**	0.862	50.8	2,600	0.76
1971	29	-6.129	1.682**	0.173	-3.588	2.919**	0.966	50.8	2,647	1.58
1972	31	-4.677	1.183	0.052	-4.234	3.095**	0.964	50.8	2,746	0.97
1973	105	-8.040	1.995**	0.219	-3.516	2.906**	0.938	50.8	2,700	0.80
1974	67	-7.218	1.736**	0.195	-4.001	3.026**	0.960	50.8	2,643	0.65
1976	104	-3.863	0.888	0.083	-3.558	2.918**	0.953	50.8	2,706	0.67
1977	51	-7.593	1.759**	0.258	-3.969	3.008**	0.960	50.8	2,569	0.52
1978	30	-1.207	0.220	0.007	-3.170	2.812**	0.960	50.8	2,607	0.66
1979	30	-1.891	0.365	0.016	-4.035	3.021**	0.913	50.8	2,525	0.62
1980	30	-8.931	2.098**	0.252	-3.431	2.867**	0.966	50.8	2,507	0.51

Covariance: Slopes: F = 1.923* (9,561) Slopes: F = 0.380 (9,561)

Means: F = 12.948** (9,578) Means: F = 2.974* (9,578)

TABLE C-3

CHANNEL CATFISH: Regression Coefficients

Year	N	log (Hg) on log length			log weight on log length			adjusted group means		
		A_o	A_1	r^2	A_o	A_1	r^2	length(cm)	weight(g)	(Hg) (mg/Kg)
1970	51	-2.620	0.673*	0.131	-4.241	2.960**	0.951	48.2	1,399	1.04
1971	13	-1.118	0.368	0.003	-8.125	3.978**	0.878	48.2	1,568	1.28
1972	63	-6.949	1.814**	0.161	-3.743	2.861**	0.827	48.2	1,533	1.11
1973	100	-5.850	1.463**	0.268	-5.444	3.286**	0.964	48.2	1,484	0.84
1974	59	-6.219	1.558**	0.422	-5.061	3.120**	0.951	48.2	1,538	0.83
1976	55	-2.423	0.529*	0.062	-3.877	2.907**	0.948	48.2	1,590	0.65
1977	51	-6.940	1.589**	0.558	-4.905	3.159**	0.955	48.2	1,530	0.44
1978	30	-5.521	1.253*	0.246	-5.118	3.201**	0.960	48.2	1,457	0.51
1979	30	-6.330	1.544*	0.175	-4.436	3.022**	0.804	48.2	1,447	0.71
1980	30	-12.789	3.137**	0.615	-5.401	3.265**	0.882	48.2	1,423	0.58

Covariance: Slopes F = 4.150** (9,479) Slopes: F = 1.823 (9,479)

Means: F = 29.90** (9,496) Means: F = 4.012** (9,496)

TABLE C-4

FRESH WATER DRUM: Regression Coefficients

Year	N	log (Hg) on log length			log weight on log length			adjusted group means		
		A_o	A_1	r^2	A_o	A_1	r^2	length(cm)	weight(g)	(Hg) (mg/Kg)
1971	30	-7.535	2.198**	0.237	-5.164	3.220**	0.938	30.3	336	0.94
1972	47	-11.348	3.180**	0.426	-5.641	3.344**	0.969	30.3	315	0.58
1973	102	-8.839	2.469**	0.550	-4.935	3.144**	0.972	30.3	325	0.65
1974	62	-14.321	4.045**	0.747	-5.215	3.216**	0.990	30.3	313	0.53
1978	30	-8.568	2.245**	0.712	-4.860	3.093**	0.931	30.3	293	0.40
1979	30	-4.098	0.985**	0.184	-4.981	3.153**	0.929	30.3	320	0.43

Covariance: Slopes: F = 7.187** (5,289) Slopes: F = 0.773 (5.289)

Means: F = 10.801** (5,298) Means: F = 3.27** (5,298)

TABLE C-5

PIKE: Regression Coefficients

Year	N	log (Hg) on log length			log weight on log length			adjusted group means		
		A_o	A_1	r^2	A_o	A_1	r^2	length (cm)	weight (g)	(Hg) (mg/Kg)
1970	29	-2.003	0.657	0.017	-5477	3.117**	0.960	66.7	2026	2.20
1971	43	-1.4050	0.626	0.019	-4.670	2.932**	0.891	66.7	2096	3.46
1972	38	2.793	-0.329	0.010	-5.438	3.104**	0.935	66.7	2008	3.69
1973	101	-7.012	1.866**	0.488	-4.740	2.936**	0.962	66.7	1995	2.26
1974	50	-6.153	1.620**	0.289	-4.639	2.913**	0.972	66.7	1972	1.93
1976	50	-6.870	1.713**	0.209	-6.134	3.272**	0.967	66.7	2023	1.39
1977	17	-7.179	1.814**	0.325	-6.004	3.222**	0.969	66.7	1882	1.58
1978	22	-8.832	2.155**	0.519	-5.082	3.017**	0.981	66.7	1983	1.24
1979	26	-6.351	1.556**	0.284	-6.155	3.268**	0.953	66.7	1965	1.20
1980	24	-9.743	2.335**	0.640	-4.768	2.929**	0.966	66.7	1895	1.00

Covariance: Slopes: F = 1.851** (9,397)
Means: F =22.291** (9,414)

Slopes: F = 1.944 (9,397)
Means: F = 2.289 (9,414)

TABLE 6

REDHORSE SUCKER: Regression Coefficients

Year	N	log (Hg) on log length			log weight on log length			adjusted group means		
		A_o	A_1	r^2	A_o	A_1	r^2	length(cm)	weight(g)	(Hg) (mg/Kg)
1972	30	-11.816	3.291**	0.276**	-4.880	3.197**	0.985	37.8	839	1.13
1973	51	-13.295	3.642**	0.447	-4.301	3.034**	0.961	37.8	833	0.92
1974	51	-9.892	2.636**	0.300	-5.028	3.224**	0.961	32.8	799	0.73
1978	30	-9.475	2.430**	0.589	-4.860	3.183**	0.990	37.8	813	0.53
1979	30	-9.184	2.263**	0.377	-4.223	2.988**	0.945	37.8	760	0.38
1980	30	-6.297	1.350	0.099	-5.325	3.282*	0.903	37.8	748	0.21

Covariance: Slopes: F = 1.495 (5,210) Slopes: F = 1.010 (5,210)

Means: F = 21.906** (5,219) Means: F = 4.196* (5,219)

TABLE 7

ROCK BASS: Regression Coefficients

Year	N	log (Hg) on log length			log weight on log length			adjusted group means		
		A_o	A_1	r^2	A_o	A_1	r^2	length(cm)	weight(g)	(Hg) (mg/Kg)
1970	35	-3.774	1.370	0.063	-3.533	2.916**	0.938	19.4	168	1.31
1971	40	-2.986	1.342*	0.180	-3.394	2.890**	0.953	19.4	178	2.60
1972	315	-5.477	2.046**	0.486	-3.621	2.939**	0.943	19.4	164	1.83
1973	112	-7.212	2.443**	0.690	-3.719	2.974**	0.952	19.4	165	1.04
1974	69	-7.000	2.335**	0.601	-3.182	2.783**	0.950	19.4	160	0.94
1976	77	-7.367	2.408**	0.425	-3.162	2.787**	0.956	19.4	165	0.81
1977	57	-9.242	2.965**	0.622	-2.738	2.647**	0.943	19.4	165	0.67
1978	30	-8.679	2.770**	0.774	-3.778	2.982**	0.964	19.4	159	0.63
1979	30	-7.050	2.258**	0.494	-3.273	2.825**	0.951	19.4	165	0.71
1980	30	-9.394	2.942**	0.715	-3.133	2.770**	0.986	19.4	163	0.50

Covariance: Slopes: F = 2.668* (1,858) Slopes: F = 1.718 (9,858)

Means: F = 114.505** (9,875) Means: F = 3.519 (9.875)

TABLE 8

SMALLMOUTH BASS: Regression Coefiicients

Year	N	log (Hg) on log length			log weight on log length			adjusted group means		
		A_o	A_1	r^2	A_o	A_1	r^2	length(cm)	weight(g)	(Hg) (mg/Kg)
1970	23	-2.947	1.019	0.063	-2.654	2.601**	0.890	33.0	630	1.87
1971	79	-6.205	2.100**	0.440	-4.773	3.215**	0.982	33.0	643	3.11
1972	87	-4.707	1.569**	0.383	-4.233	3.046**	0.979	33.0	613	2.18
1973	66	-8.470	2.478**	0.631	-4.600	3.169**	0.976	33.0	652	1.21
1974	45	-7.192	2.100**	0.681	-4.170	3.018**	0.990	33.0	594	1.18
1976	28	-4.722	1.346**	0.242	-2.622	2.593**	0.970	33.0	620	0.93
1977	54	-4.461	1.199**	0.338	-4.132	3.032**	0.973	33.0	644	0.78
1978	30	-7.870	2.118**	0.721	-4.011	2.984**	0.983	33.0	615	0.62
1979	30	-7.306	1.984**	0.542	-3.779	2.922**	0.970	33.0	622	0.70
1980	30	-6.921	1.877**	0.520	-4.126	3.023**	0.976	33.0	631	0.70

Covariance: Slopes: F = 2.383* (9,478) Slopes: F = 7.501** (9,478)

Means: F = 98.676** (9,495) Means: F = 4.331 (9,495)

TABLE 9

WALLEYE: Regression Coefficients

Year	N	log (Hg) on log length			log weight on log length			adjusted group means		
		A_o	A_1	r^2	A_o	A_1	r^2	length(cm)	weight(g)	(Hg) (mg/Kg)
1970	611	-0.833	0.334	0.043	-4.560	2.989**	0.937	36.9	505	1.49
1971	350	-4.193	1.261**	0.428	-4.958	3.169**	0.986	36.9	520	1.41
1972	436	-4.357	1.271**	0.629	-5.052	3.142**	0.991	36.9	528	1.21
1973	291	-6.701	1.181**	0.613	-4.771	3.068**	0.989	36.9	542	0.88
1974	590	-5.914	1.549**	0.704	-4.949	3.106**	0.989	36.9	521	0.75
1976	246	-8.181	2.056**	0.462	-4.805	3.060**	0.964	36.9	509	0.58
1977	62	-11.940	3.055**	0.764	-4.677	3.031**	0.974	36.9	518	0.62
1978	30	-10.212	2.521**	0.765	-5.206	3.163**	0.990	36.9	505	0.45
1979	50	-9.498	2.426**	0.442	-4.898	3.094**	0.984	36.9	529	0.60
1980	30	-12.058	3.064**	0.563	-4.631	3.014**	0.961	36.9	507	0.58

Covariance: Slopes F = 65.686** (9,3220) Slopes: F = 4.489** (9,3220)

Means: F = 136.067** (9,3238) Means: F = 4.987** (9,3238)

TABLE 10

WHITE BASS: Regression Coefficients

Year	N	log (Hg) on log length			log weight on log length			adjusted group means		
		A_o	A_1	r^2	A_o	A_1	r^2	length(cm)	weight(g)	(Hg) (mg/Kg)
1970	57	0.748	-0.172	0.002	-4.560	3.151**	0.947	28.0	379	1.22
1972	55	-11.538	3.607**	0.485	-4.579	3.169**	0.959	28.0	395	1.60
1973	91	-4.485	1.321**	0.243	-4.461	3.126**	0.977	28.0	386	0.93
1974	70	-10.792	3.178**	0.706	-5.272	3.369**	0.990	28.0	378	0.73
1976	65	- 4.509	1.236*	0.089	-3.558	2.871**	0.949	28.0	395	0.66
1977	61	-16.888	4.850**	0.684	-4.273	3.096**	0.966	28.0	392	0.59
1978	30	-17.393	5.057**	0.848	-4.806	3.227**	0.982	28.0	382	0.58
1979	30	-19.332	5.542**	0.497	-4.188	3.054**	0.971	28.0	397	0.48
1980	30	-14.222	4.048**	0.810	-4.875	3.249**	0.985	28.0	384	0.48

Covariance: Slopes: F - 18.749** (8,548) Slopes: F = 2.588* (8,548)

Means F = 21.551** (8,563) Means: F = 1.572 (8,563)

TABLE 11

WHITE SUCKER: Regression Coefficients

Year	N	log (Hg) on log length			log weight on log length			adjusted group means			
		A_o	A_1	r^2	A_o	A_1	r^2	length(cm)	weight(g)	(Hg)	(mg/kg)
1973	36	-7.653	2.095*	0.067	-2.915	2.635**	0.765	40.1	900		1.09
1974	51	-3.567	0.979**	0.143	-4.384	3.022**	0.987	40.1	876		1.05
1976	51	-16.343	4.328**	0.306	-3.609	2.808**	0.879	40.1	859		0.71
1977	23	-21.496	5.608**	0.338	-3.776	2.859**	0.901	40.1	874		0.55
1978	30	-11.088	2.717**	0.449	-4.444	3.026**	0.983	40.1	832		0.33
1979	30	-24.817	6.376**	0.281	-3.942	2.900**	0.815	40.1	866		0.28
1980	30	-6.938	1.437*	0.069	-4.213	2.977**	0.903	40.1	880		0.20

Covariance: Slopes: F = 4.829** (6,237) Slopes: F = 0.826 (6,237)
Means: F =30.955** (6,248) Means: F = 1.226 (6,248)

TABLE 12

YELLOW PERCH: Regression Coefficients

Year	N	log (Hg) on log length			log weight on log length			adjusted group means		
		A_o	A_1	r^2	A_o	A_1	r^2	length(cm)	weight(g)	(Hg) (mg/Kg)
1970	245	-4.053	1.465**	0.094	-4.446	3.035**	0.775	17.0	62	1.22
1971	70	-2.387	0.937**	0.414	-4.892	3.208**	0.992	17.0	67	1.31
1972	357	-2.427	0.738*	0.147	-4.767	3.143**	0.982	17.0	63	0.73
1973	375	-4.523	1.295**	0.392	-4.963	3.218**	0.980	17.0	64	0.41
1974	259	-3.996	1.008**	0.531	-4.848	3.166**	0.987	17.0	62	0.32
1976	14	-8.536	2.645	0.185	-4.852	3.173**	0.971	17.0	63	0.55
1977	54	10.966	3.187**	0.426	-4.771	3.159**	0.959	17.0	65	0.27
1978	30	-8.369	2.409**	0.497	-6.033	3.546**	0.974	17.0	64	0.36
1979	10	-4.123	1.043	0.094	-4.803	3.158**	0.968	17.0	63	0.32
1980	27	-6.414	1.660*	0.110	-5.171	3.287**	0.959	17.0	65	0.21

Covariance: Slopes: F = 4.645** (9,1446) Slopes: F = 1.240 (9,1446)

Means: F = 125.383** (9,1464) Means: F = 1.969* (9,1464)